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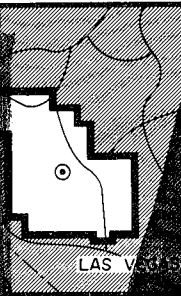
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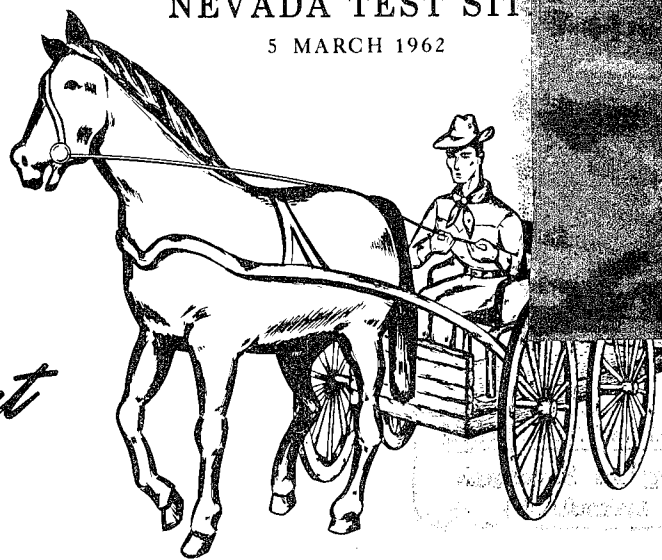
DANNY BOY

NEVADA TEST SITE

5 MARCH 1962



Final Report



CLOSE-IN AIR BLAST FROM A NUCLEAR
DETONATION IN BASALT

L. J. Vortman

SANDIA CORPORATION

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PROJECT 1.1b

CLOSE-IN AIR BLAST FROM A NUCLEAR DETONATION IN BASALT

L. J. VORTMAN

Sandia Corporation
Albuquerque, New Mexico

June 1962



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ABSTRACT

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ACKNOWLEDGEMENTS

The author wishes to thank Mr. D. P. LeFevre, Ballistic Research Laboratories, for making the blast measurements and reducing the data for Project Danny Boy and Mr. F. Shoemaker for coordinating the project in the field.

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CONTENTS

ABSTRACT	2
CHAPTER 1 INTRODUCTION	5
1.1 Objective.	5
1.2 Background	5
1.3 Instrumentation.	6
CHAPTER 2 TEST RESULTS	10
2.1 Summary of Results	10
2.2 Peak Overpressure.	10
2.3 Positive Phase	10
2.4 Arrival Times.	10
CHAPTER 3 DISCUSSION	20
3.1 Wave Shape	20
3.2 Peak Overpressure.	21
3.3 Positive-Phase Impulse	22
3.4 Positive-Phase Duration.	22
3.5 Explosive Implications	22
CHAPTER 4 CONCLUSIONS.	27
REFERENCES	28

FIGURES

1.1 Typical Waveforms from Buried HE and Nuclear Detonations . . .	7
1.2 Typical Gage Installation.	8
1.3 Cleared Area Around Gage Installation.	8
1.4 Self-Recording Pressure-Time Gage.	9
2.1 Pressure Records	12
2.2 Pressure Records	13
2.3 Pressure Records	14
2.4 Pressure Records	15
2.5 Maximum Overpressure versus Ground Range	16
2.6 Positive Impulse versus Ground Range	17
2.7 Positive-Phase Duration versus Ground Range.	18
2.8 Arrival Time versus Ground Range	19
3.1 Maximum Overpressure versus Scaled Ground Range.	24
3.2 Scaled Positive Impulse versus Scaled Ground Range	25
3.3 Scaled Positive-Phase Duration versus Scaled Ground Range. . .	26

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-5-

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

The objective of the air blast measurement program was to determine the overpressure-time-distance relationship at ground level along one blast line for the purpose of determining the extent of close-in blast suppression. This experiment extends blast observations from charges buried in basalt to 430 tons, a yield larger by a factor of 20 than yields of Project Buckboard. The new data permit some indication of the extent to which differences in close-in blast can be attributed to differences in the type of explosive used (nuclear or chemical explosive).

1.2 BACKGROUND

Close-in air blast along the ground surface has been measured on underground detonations from high explosives in Nevada Test Site desert alluvium using high-explosive charges of 256 (References 1, 2, and 3), 2,560 (Reference 1), 40,000 (References 1 and 4), and 1,000,000 (Reference 5) pounds. It has also been observed on a surface nuclear detonation (References 6 and 7) and on two relatively shallow nuclear detonations (References 6, 7, and 8) in the same medium. On Project Buckboard (Reference 9) blast overpressures were measured along the ground from three 40,000-pound detonations at three different burst depths in basalt. The Buckboard experiments led to the conclusion that no difference in the suppression of peak overpressure is attributable to the harder medium; that is, with high explosives, suppression of peak overpressure is essentially the same in alluvium and basalt.

A typical overpressure waveform from an underground high-explosive detonation shows a ground-shock-induced pressure pulse (often referred to as the "front porch") followed by the main portion of the blast wave

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generated by the venting of the explosion gases (Figure 1.1a). The waveforms from Project Danny Boy (Figure 1.1b) are explained later.

1.3 INSTRUMENTATION

1.3.1 Gage Locations

Gages were located along an approximately SE radius at radial distances along the ground at 200, 265, 350, 470, 630, 840, 1120, 3100, and 8500 feet. Typical gage installations are shown in Figure 1.2. Figure 1.3 shows the completed gage installation with the cleared area immediately around the gage. This photograph was taken looking toward surface zero.

1.3.2 Gage Types

Measurements were made using Ballistic Research Laboratories self-recording pressure gages (Figure 1.4). In these gages, a battery-operated motor drives a turntable carrying either an aluminized glass disc or a stainless steel disc. A pressure sensitive diaphragm, connected directly to a scribe, permits the pressure record to be inscribed on the disc as the turntable rotates. The gage motor is started by a timing signal at -1 second. Standard pressure-time gages (PT's) were used at Stations 1 through 7, and very low pressure gages (VLP's) were used at Stations 6 through 9). Both types of gages were installed at Stations 6 and 7.

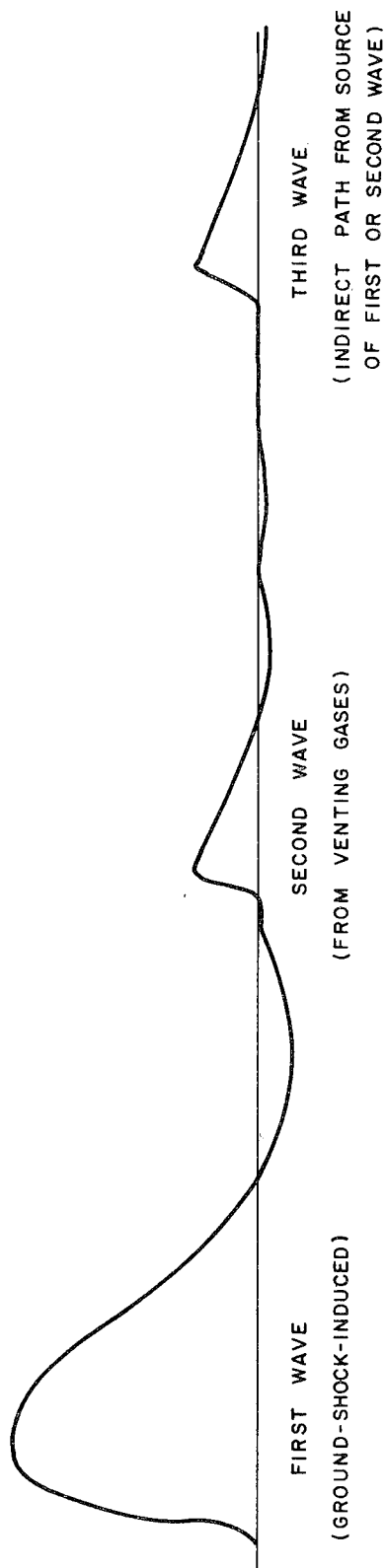
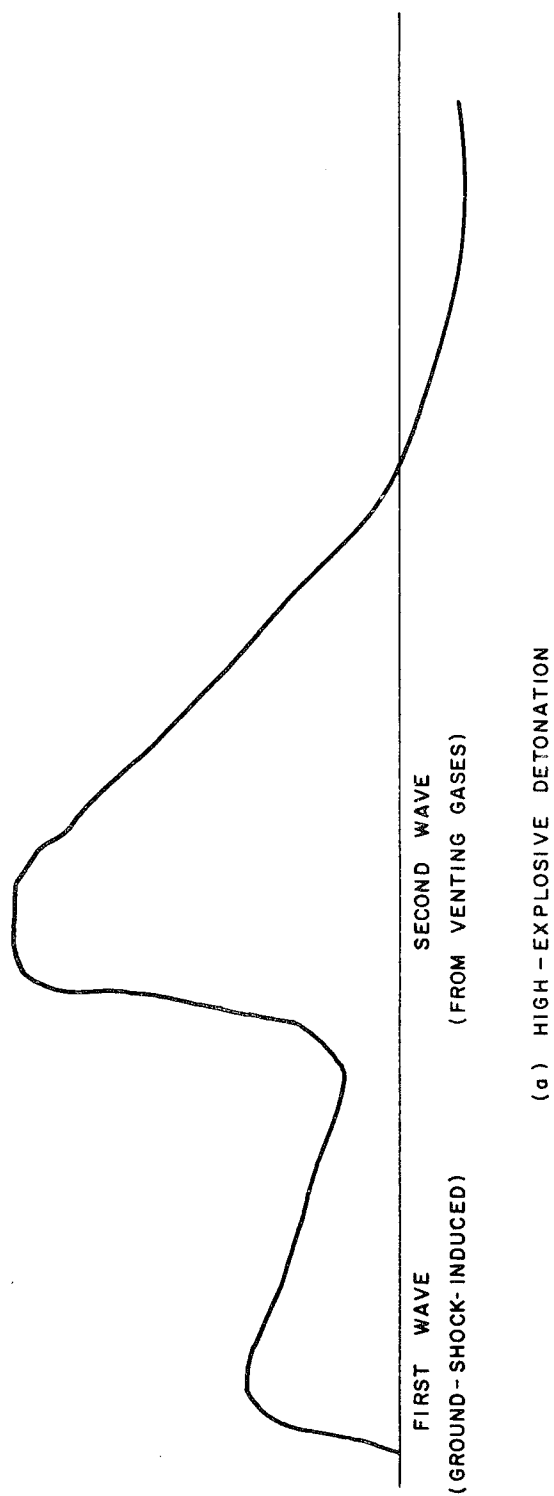


Figure 1.1 Typical Waveforms from Buried HE and Nuclear Detonation

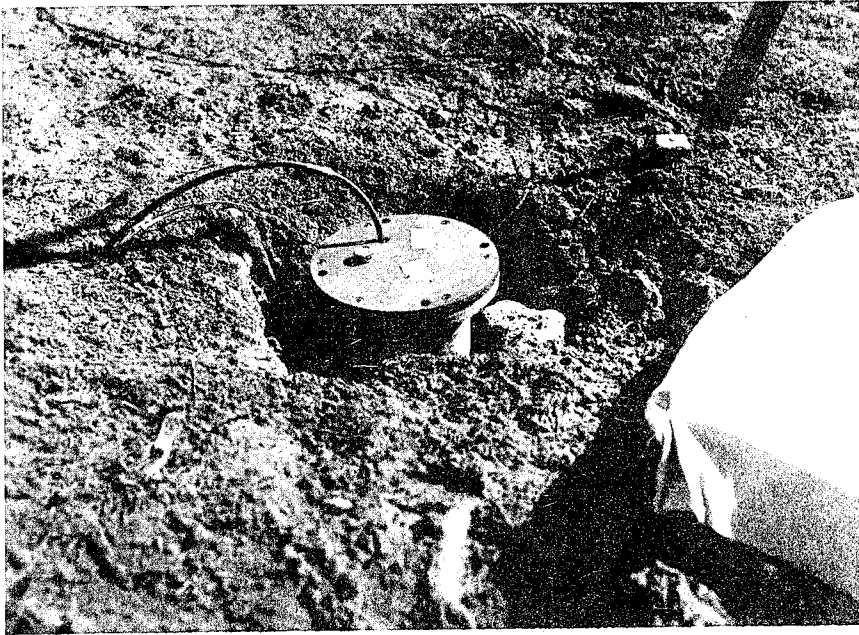


Figure 1.2 Typical Gage Installation



Figure 1.3 Cleared Area Around Gage Installation

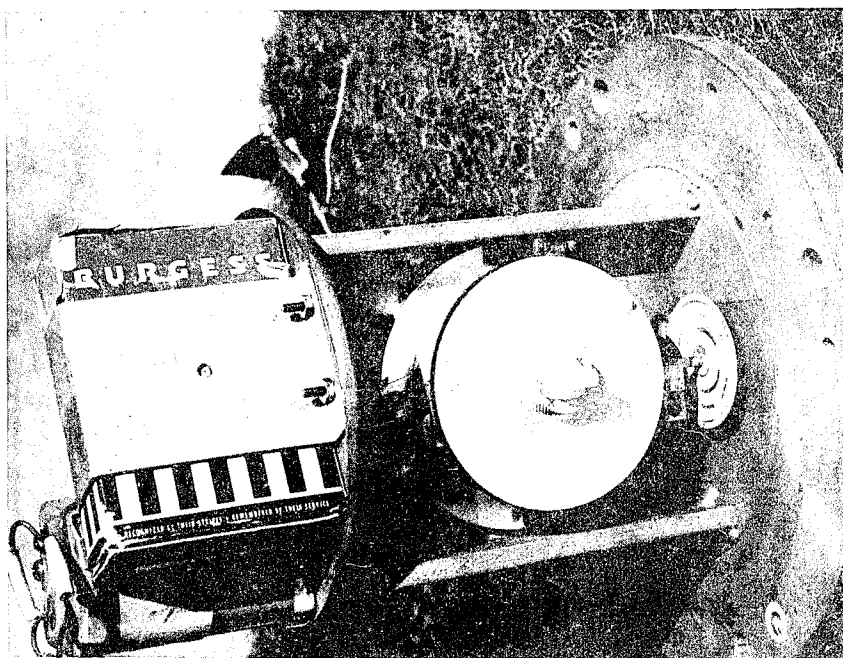
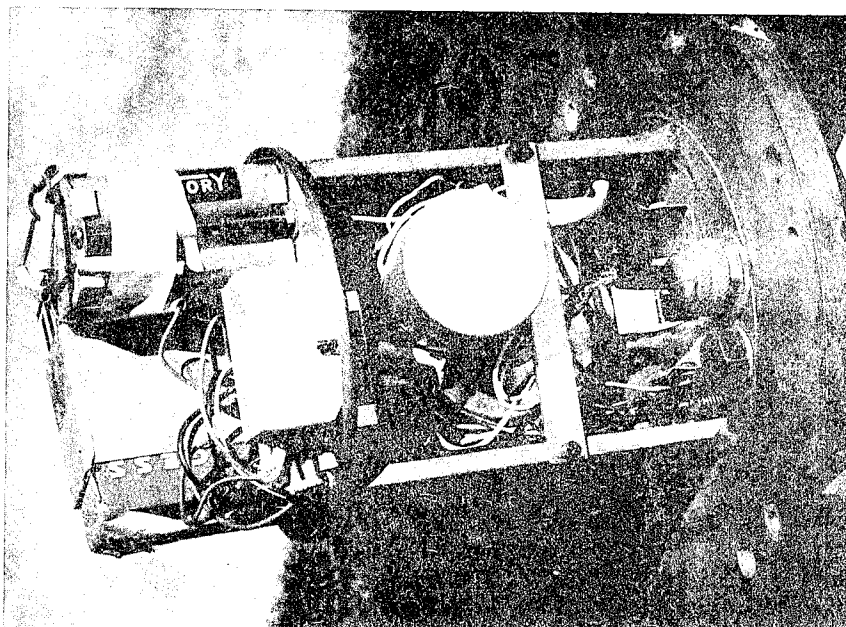


Figure 1.4 Self-Recording Pressure-Time Gage

CHAPTER 2

TEST RESULTS

2.1 SUMMARY OF RESULTS

Table 2.1 summarizes the results of the pressure measurements. Because peak pressures only were obtained at Stations 5, 6B, 7B, and 8, records of pressure-time are not reproduced. Pressure records from the remaining seven gages are shown in Figures 2.1 through 2.4. Time in the figures is time from the arrival of the signal shown. The pressure wave illustrated is the first wave in all cases except at the 3100-foot station (Station 8), where the wave shown, as explained later, is from another source.

2.2 PEAK OVERPRESSURE

Figure 2.5 shows peak overpressures as a function of ground range. Also shown is the curve predicted before the shot for a slightly larger yield and a comparatively deeper burst depth; set ranges of the gages were based upon this curve. As indicated by the figure, all pressure records obtained were one-third to one-half of the set range.

2.3 POSITIVE PHASE

The positive-phase impulse of the pressure records is shown in Figure 2.6. The duration of the positive phase as a function of ground range is given in Figure 2.7. As is usual in pressure measurements, the scatter in positive-phase duration data is considerably greater than that in either peak overpressure or positive-phase impulse.

2.4 ARRIVAL TIMES

Arrival times are plotted in Figure 2.8.

TABLE 2.1 SUMMARY OF RESULTS

<u>Station</u>	<u>Ground range (feet)</u>	<u>Type of gage</u>	<u>Capsule range (psi)</u>	<u>Peak pressure (psi)</u>	<u>Arrival time (sec)</u>	<u>Positive- phase duration (sec)</u>	<u>Positive- phase impulse (psi-msec)</u>
1	200	PT	1/2	.255	-	.276	48.3
2	265	PT	1/2	.16	.510	.250	23.08
				.04	1.48	.685	
3	350	PT	1/2	.11	.815	.365	21.36
				.02	1.83	.410	
4	470	PT	1/2	.12	1.075	.505	19.86
				.04	1.485	.08	
				.03	2.38	.70	
5	630	PT	1/2	.075	PEAK	ONLY	
6A	840	PT	1/2	.045	1.070	.145	3.52
6B	840	VLP	1/4	.080	PEAK	ONLY	
7A	1120	PT	1/2	.055	1.385	.345	10.47
7B	1120	VLP	1/4	.070	PEAK	ONLY	
8	3100	VLP	1/4	.027	3.64		
				.065	11.25	.125	2.72
9	8500	VLP	1/4	.060	PEAK	ONLY	

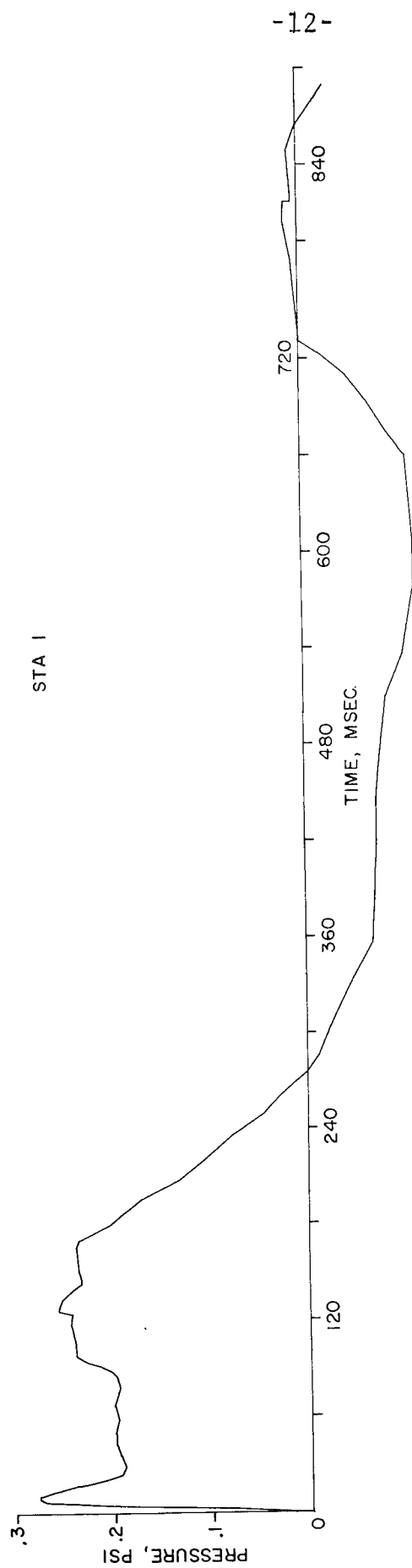


Figure 2.1 Pressure Records

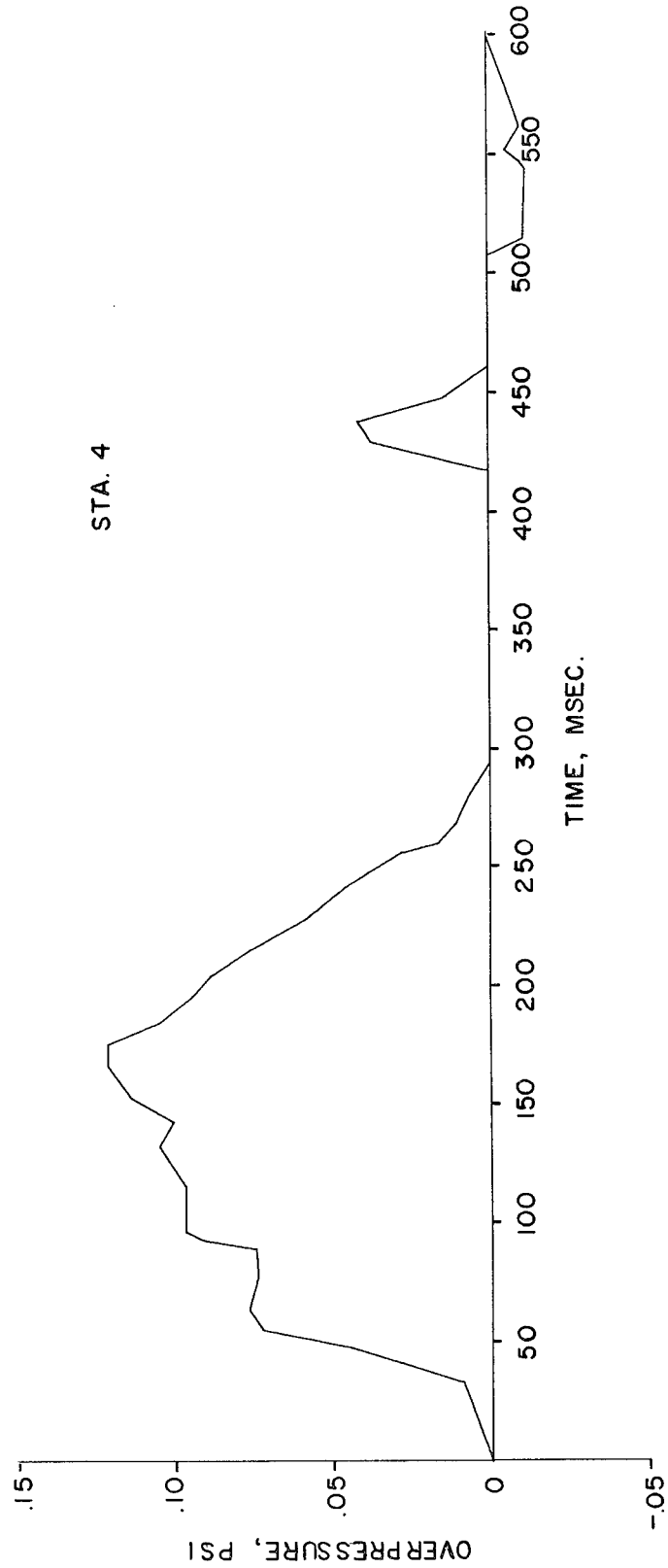
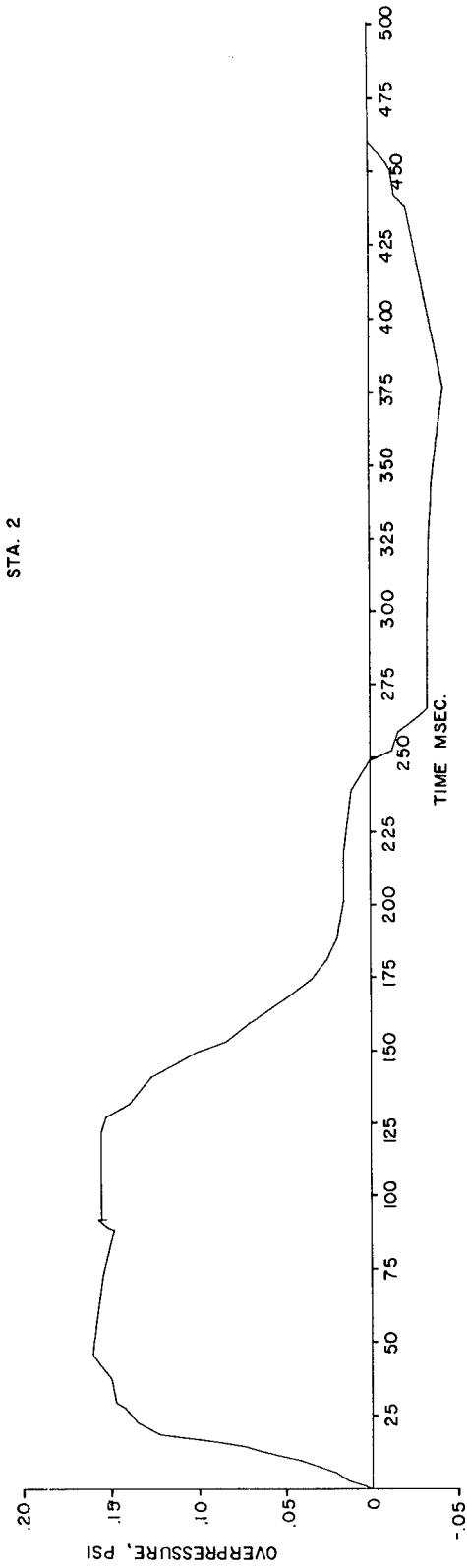


Figure 2.2 Pressure Records

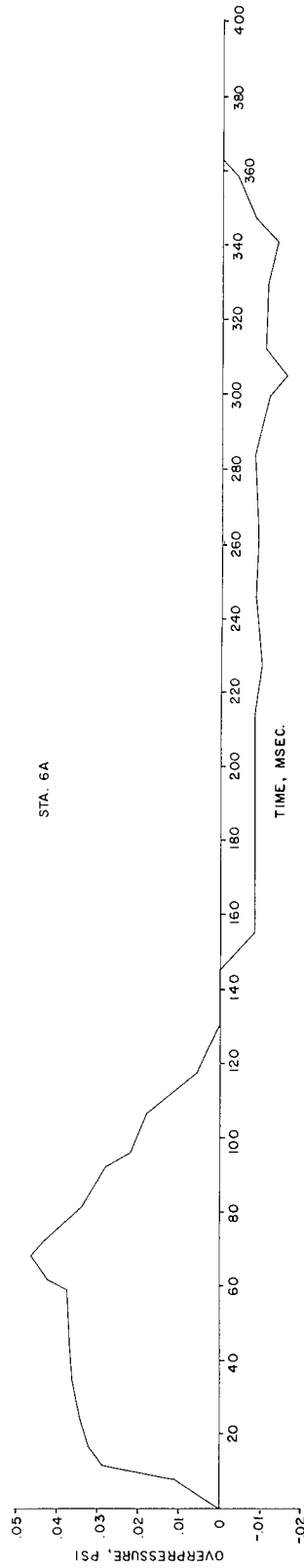
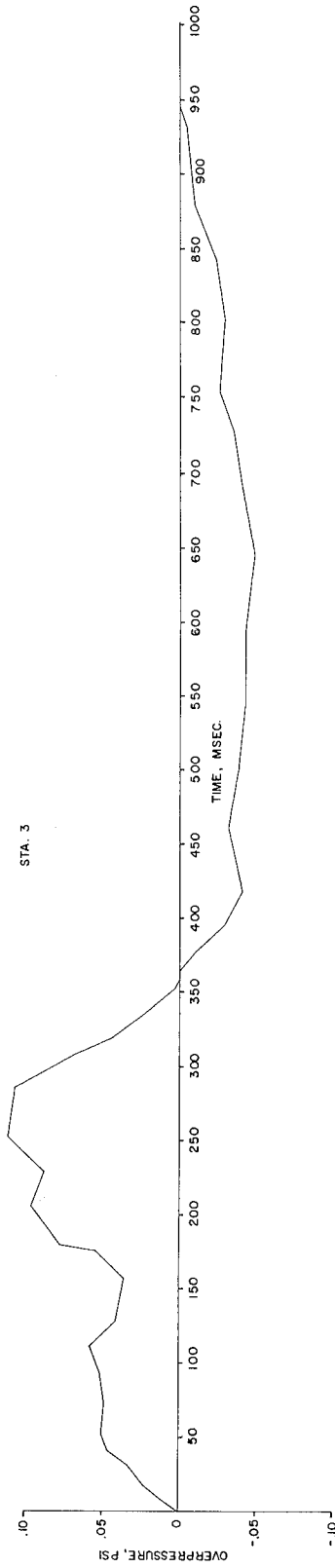
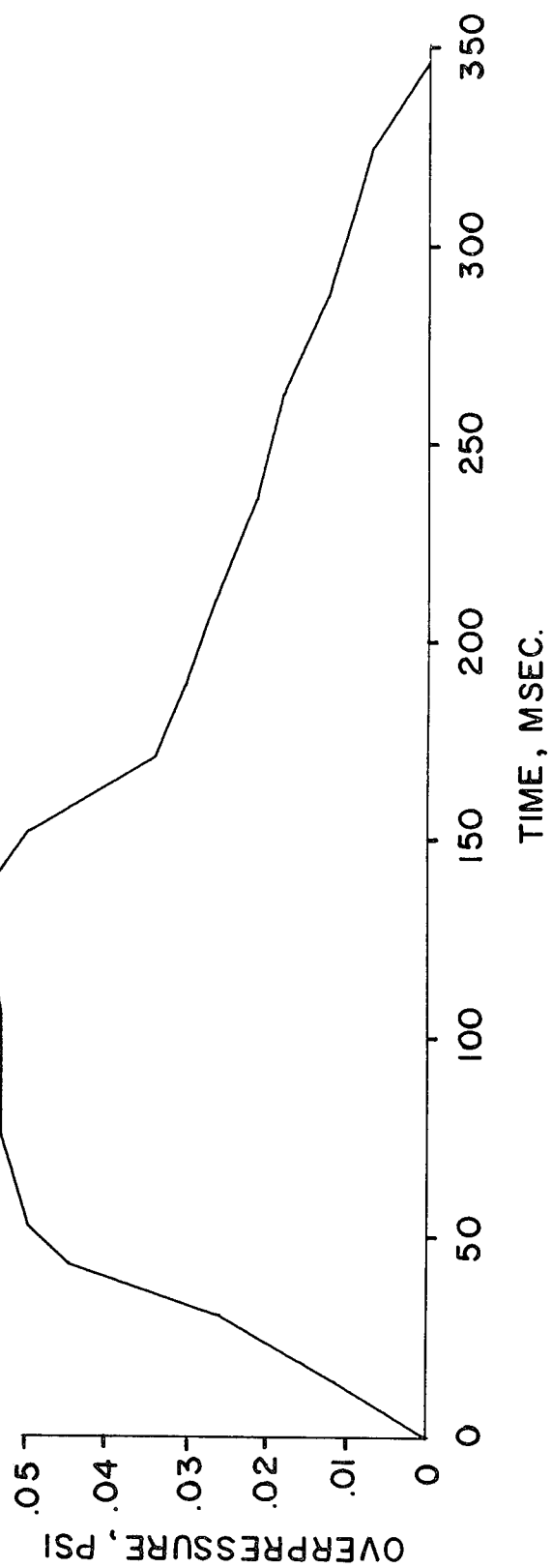


Figure 2.3 Pressure Records

STA. 7A



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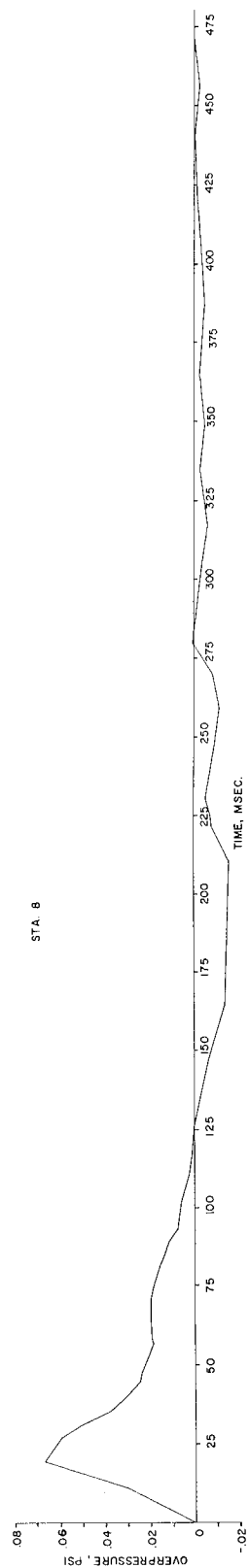


Figure 2.4 Pressure Records

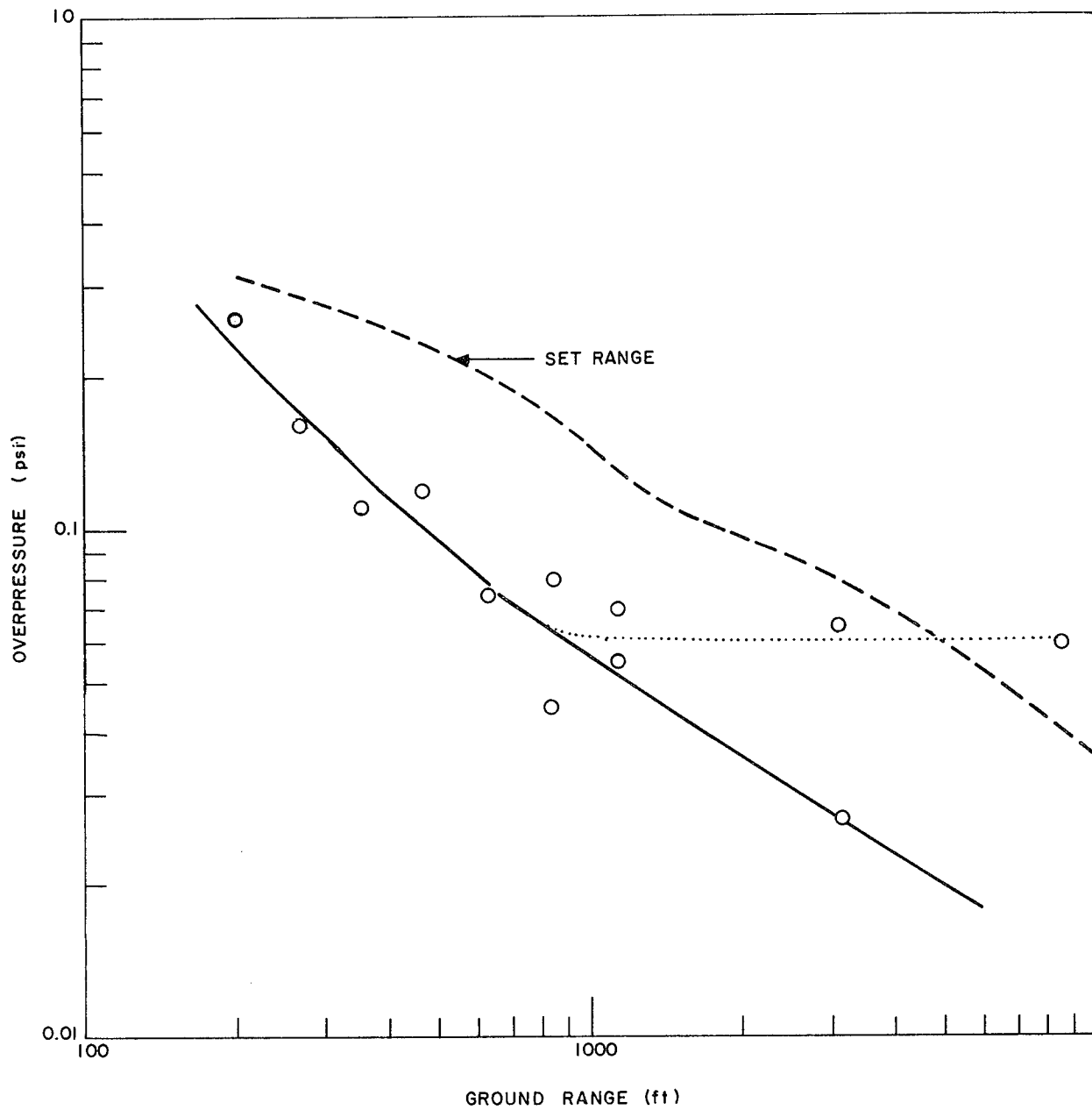


Figure 2.5 Maximum Overpressure versus Ground Range

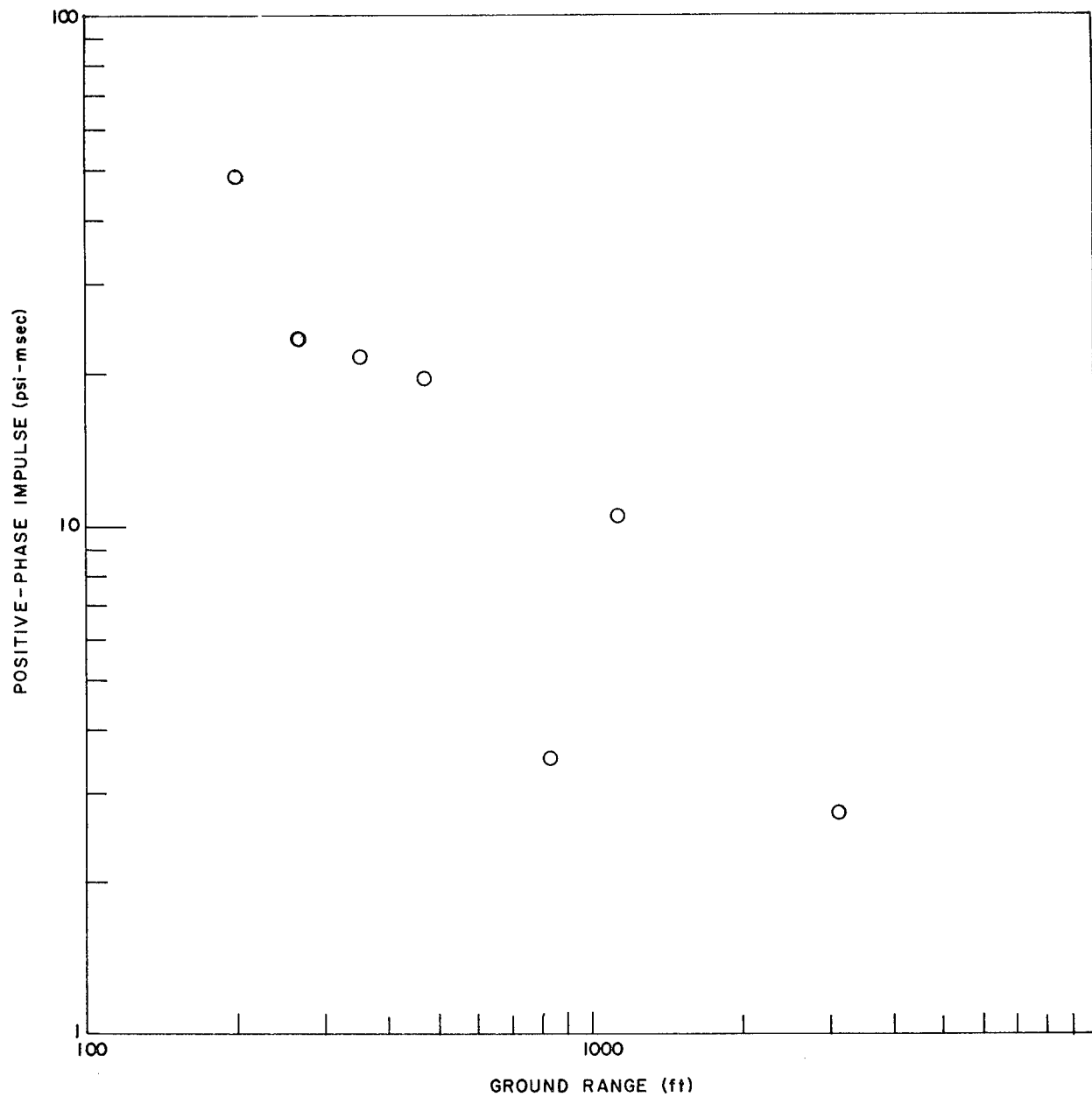


Figure 2.6 Positive Impulse versus Ground Range

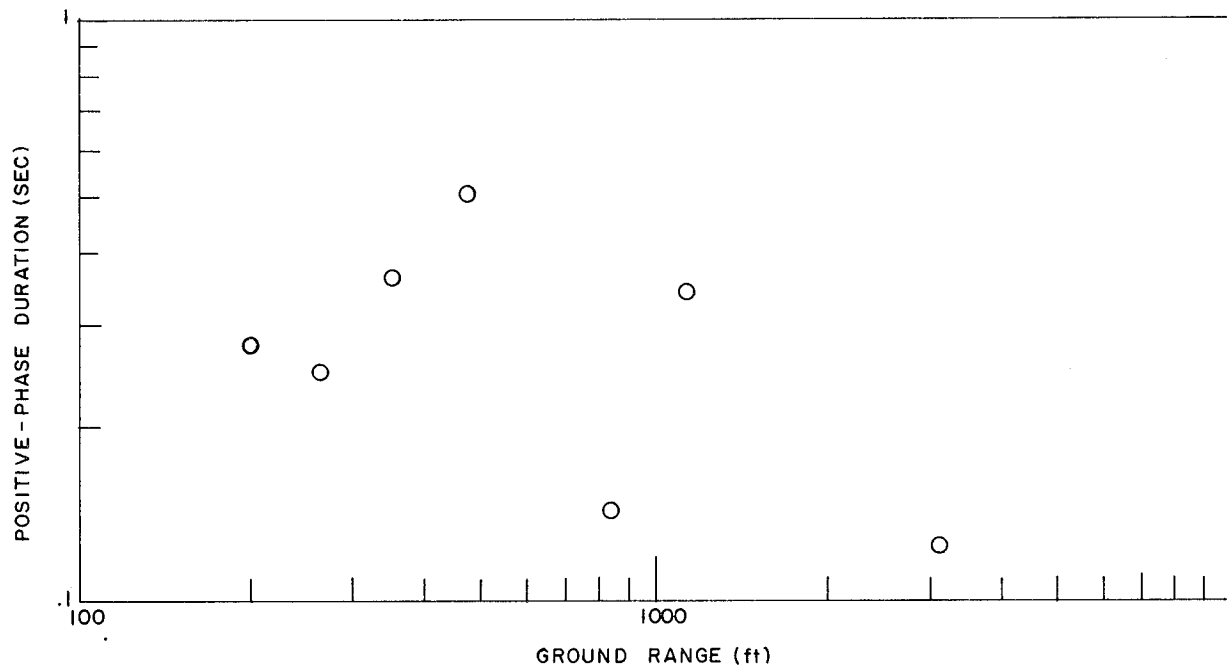


Figure 2.7 Positive Phase Duration versus Ground Range

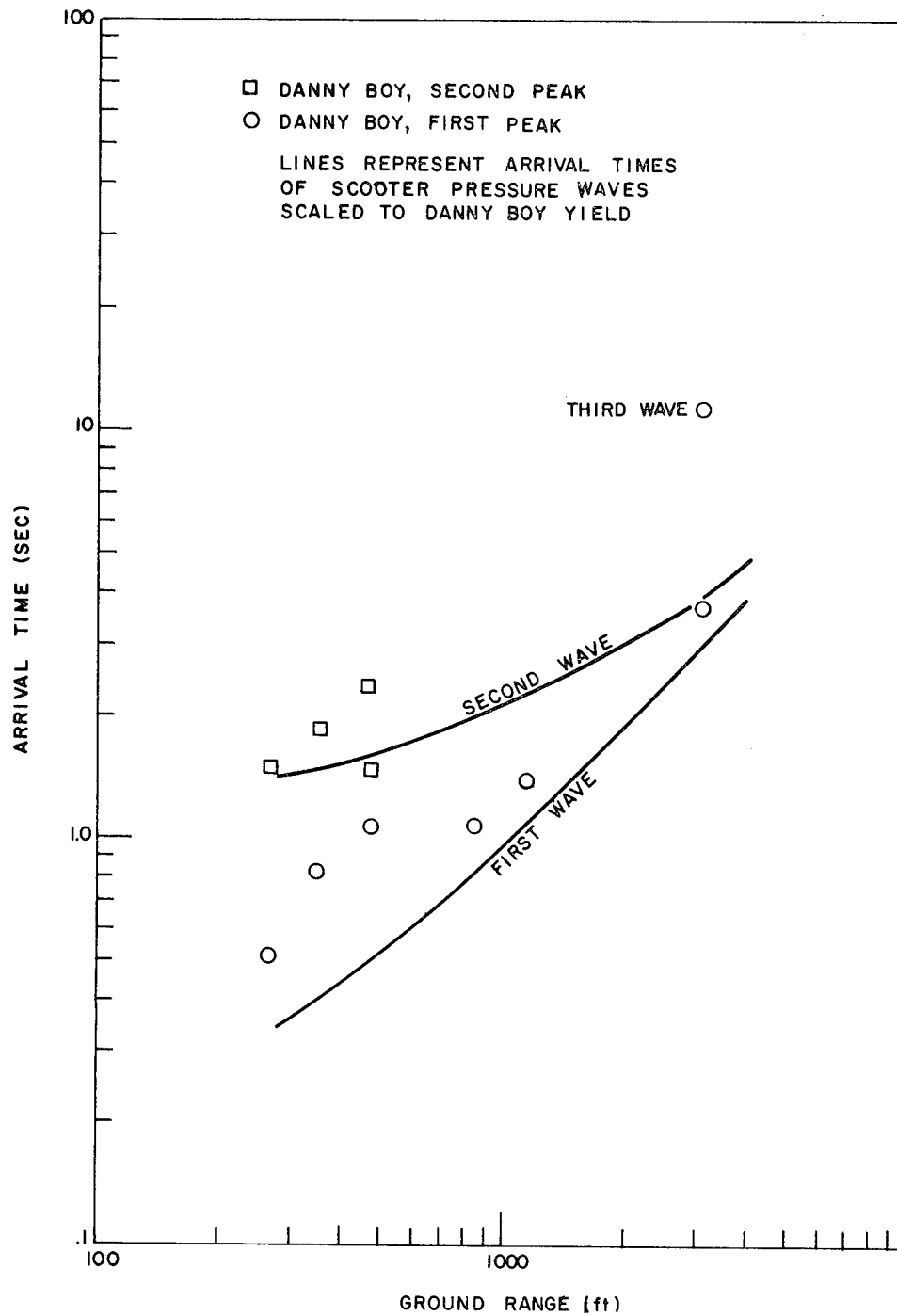


Figure 2.8 Arrival Time versus Ground Range

CHAPTER 3

DISCUSSION

3.1 WAVE SHAPE

The most unusual thing about the waveforms from the Danny Boy detonation is that upon first examination they showed only a single pressure pulse, that shown in Figures 2.1 to 2.4. This is in contrast to waveforms from high-explosive detonations in basalt and desert alluvium (Buckboard Shot 12 and Scooter) at an only slightly greater burst depth; these have shown two distinct pulses, the second one dominant.

Initial plotting of the arrival times of these waves (Figure 2.8) only added to the confusion, since they fell between those of the first and second waves of Scooter scaled to the Danny Boy yield. In addition, the arrival time at 3100 feet (Station 8) was far too late to be directly associated with the waves whose arrivals were noted from the closer stations.

Careful scrutiny revealed barely discernable signals following the main signals at the four closest stations (Stations 1, 2, 3, and 4). Plots show (Figure 2.8) that these waves follow the preceding ones by about the same interval that the Scooter waves followed the first. This suggested that the main signals were ground-shock-induced waves, and that the very weak secondary waves were caused by venting gases. These latter waves were too much attenuated to be observed at Stations 6, 7, and 8.

Similarly, close examination of the record from Station 8 shows a very weak earlier wave whose amplitude was only 0.027 psi. Its arrival time was in agreement with arrivals of the dominant (first) wave at the other stations. This fact, together with the observation that the second wave had disappeared at even closer stations, leads to the conclusion that the weaker wave was the first or ground-shock-induced wave, that the second wave had disappeared, and that the third and dominant signal at Station 8 must have had a different origin. Since amplitudes at Stations 8 and 9 are nearly the same, the wave must have attenuated very slowly. The arrival of the third wave at Station 8

at 11.25 seconds and its amplitude justify its being attributed to a 2400-pound microbarograph calibration charge detonated 11,800 feet away at zero time. Obviously, the values from this wave cannot be considered further in relation to Project Danny Boy.

3.2 PEAK OVERPRESSURE

Peak overpressures of the main (first) wave as a function of ground range scaled to a 1-pound charge are shown in Figure 3.1. The relatively constant overpressure beyond 12 ft/lb^{1/3} represents the third wave, attributed to the microbarograph calibration shot. Also shown in Figure 3.1 is a curve representing expected pressures from the second or gas-venting pulse based on high-explosive data at the same scaled burst depth. For this pulse, there was essentially no difference in peak overpressure from high explosives detonated in alluvium and basalt, and it was upon the combined data that the estimates of expected overpressures had been based. Since the arrival times (Figure 2.8) were bracketed by the arrival times of first and second pulses of Project Scooter scaled to Danny Boy yield, they could not be used without the later arrivals at the three closest stations to indicate conclusively whether the single pulse shown on the Danny Boy records represented a ground-shock-induced air shock or a gas-venting pulse.

An examination of Project Buckboard data shows that the first ("front porch") wave from Buckboard Shot 11 at a scaled burst depth of 0.75 ft/lb^{1/3} is given by $p = 1.2 r^{-.97}$, where r is the scaled ground range. For Buckboard Shot 12 at a scaled burst depth of 1.25 ft/lb^{1/3}, the relationship was $p = 0.9 r^{-1.1*}$. Interpolation between these relationships gives a predicted "front porch" wave for Danny Boy of about $p = 0.95 r^{-1.1}$. This relationship is shown in Figure 3.1. The close agreement of the measured data to this prediction is taken as final evidence that the dominant pulse measured is, in fact, the ground-shock-induced air shock. A best-fit pressure-distance relationship for the measured pressures is about $p = 0.32 r^{-.70}$. Even with this spread between measured and predicted pressures, it is clear (1) that peak pressures from the nuclear shot are less than were predicted from high-explosive data and (2) that the pressure attenuates less rapidly from the nuclear detonation than it did from high-explosive detonations in the same medium and at comparable burst depth.

*Pressures in the first wave in alluvium are less; the corresponding relationship for Scooter being $p = 0.52 r^{-1.1}$.

Peak overpressure values for the gas-venting pulse at the three closest stations are also shown in Figure 3.1. These signals are so small a part of set range that great precision cannot be obtained. They do show that the gas-venting pulse is only about one-third as large as the ground-shock-induced pulse. This is in contrast to high-explosive experience where the ground-shock-induced pulse at nearly the same scaled burst depth is about one-third of the gas-venting pulse.

All values from the gage at Station 6A are low, but a careful re-evaluation revealed no reason for modifying the numbers shown.

3.3 POSITIVE-PHASE IMPULSE

Although it is possible to define the peak overpressure associated with each portion of the blast wave, it is not worthwhile to define their positive-phase impulses. This is because the amplitudes of all but the dominant wave of Danny Boy are so low (only a few mils on the original record) and such a small portion of set range that scatter in data is especially large. Also, comparisons with high-explosive data are difficult, because there the "front porch" typically runs into the dominant wave, making it impossible to define them separately. Therefore, it was to be expected that the values measured on Project Danny Boy, consisting only of impulse from the ground-shock-induced wave, would fall below the impulses predicted from high-explosive waves, which are made up of contributions from both the ground-shock-induced and gas-venting waves (Figure 3.2).

3.4 POSITIVE-PHASE DURATION

As in the case of the positive-phase impulse, only the positive-phase duration of the dominant wave of Danny Boy can be compared with the total positive-phase duration from high explosives, which includes both first and second waves. Danny Boy results and a comparison with total positive-phase duration from high-explosive tests scaled to 1 lb are shown in Figure 3.3.

3.5 EXPLOSIVE IMPLICATIONS

Close-in air blast from above-ground detonations is known with sufficient accuracy that estimates of explosive yield can be made from pressure-distance observations. Only slightly less accurate estimates can be made for

high-explosive detonations underground where the gas-venting pulse is dominant. For nuclear charges in basalt at deeper depths below ground, as evidenced by Danny Boy where the dominant pulse is ground-shock-induced, such estimates appear to have little meaning. Because the dominant wave from the nuclear detonation appears to attenuate less rapidly than the first wave from high-explosive detonations, estimates of Danny Boy yield vary with the ground distance of the peak pressure observations from 75 tons near the closest station to 325 tons at 1120 feet.

The very small gas-pressure pulse from the Danny Boy event may be attributed to the almost total lack of moisture in the basalt. More significant, second pulses may be expected from detonations in media with greater water content or in media (such as limestone) where chemical reactions can be expected to produce higher gas pressures. These measurements are useful in determining the relative importance of gas pressure as a mechanism of crater formation and, hence, should be continued on nuclear cratering events.

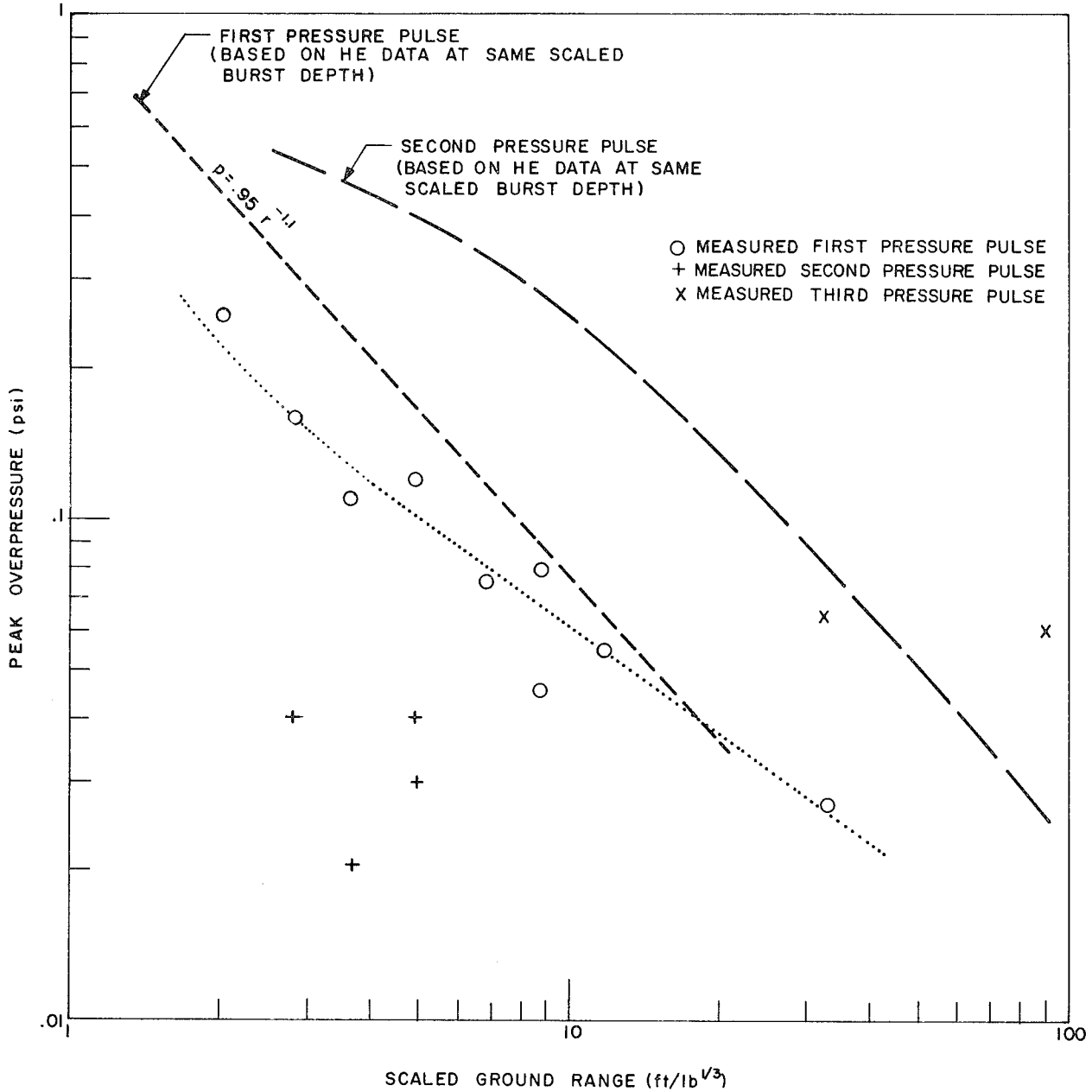


Figure 3.1 Maximum Overpressure versus Scaled Ground Range

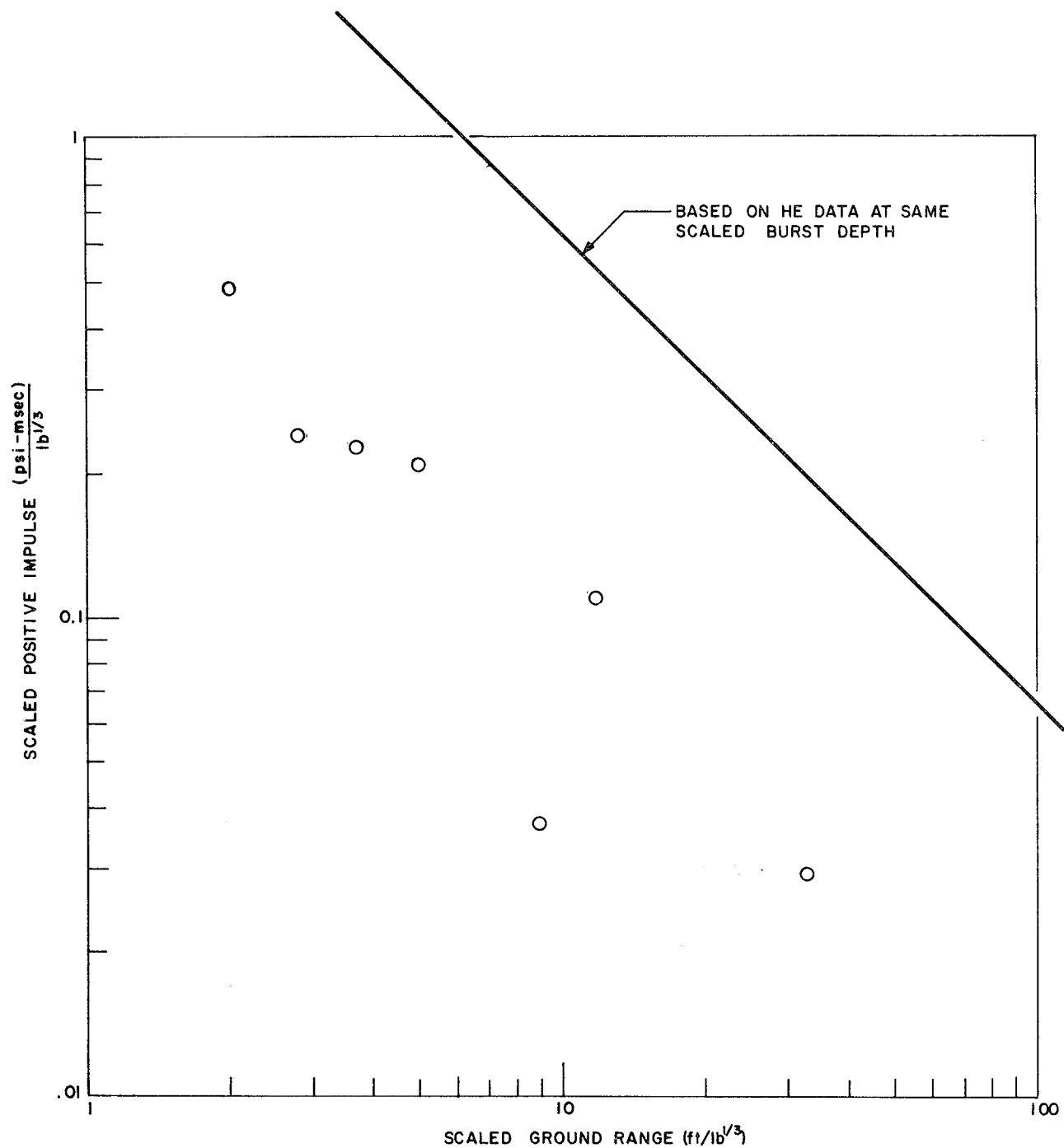


Figure 3.2 Scaled Positive Impulse versus Scaled Ground Range

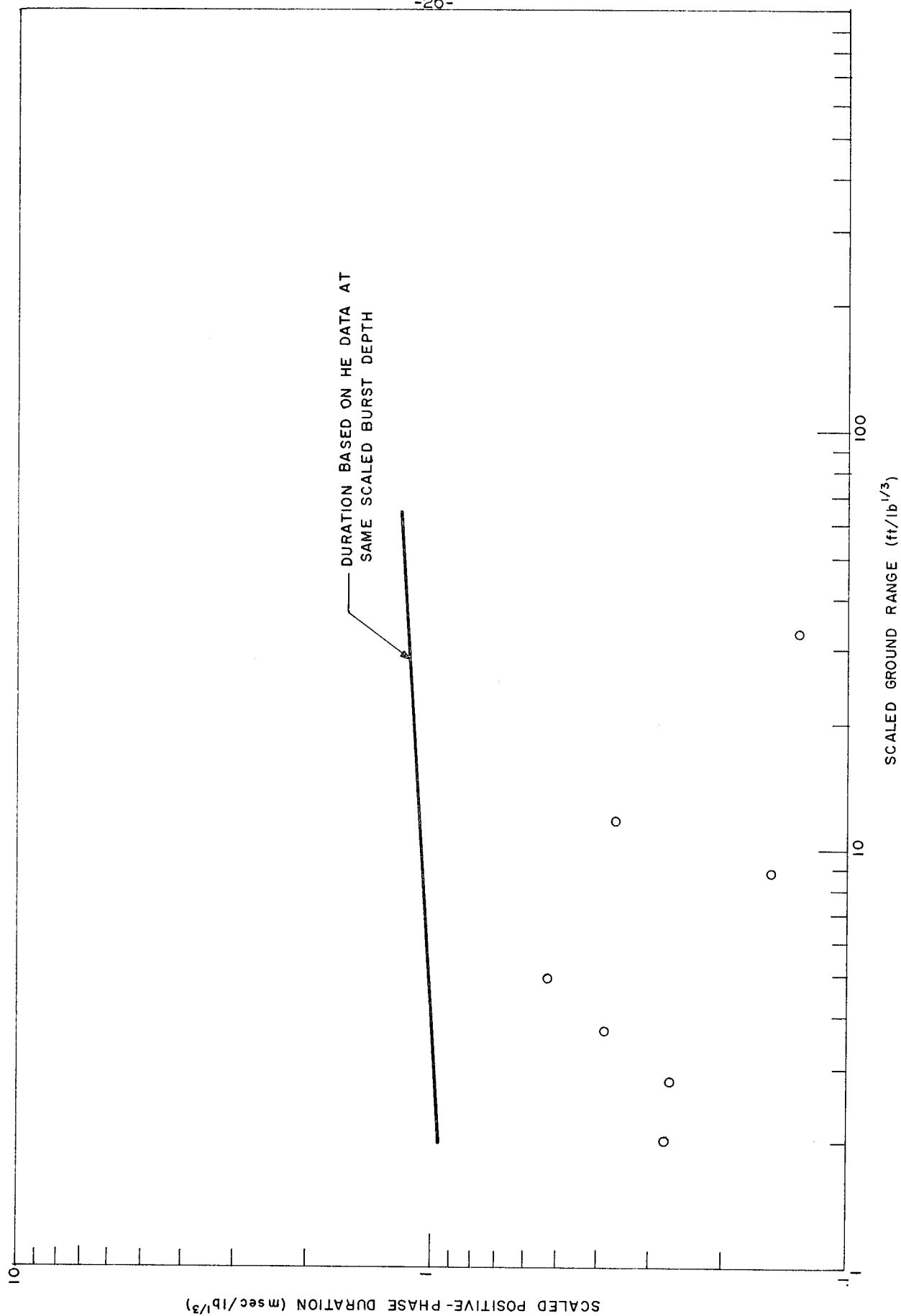


Figure 3.3 Scaled Positive Phase Duration versus Scaled Ground Range

CHAPTER 4

CONCLUSIONS

The dominant pressure pulse from the Danny Boy event is shown to have been the ground-shock-induced air blast. Only a very small pressure pulse resulting from the venting of explosive gases was recorded at the three closest stations. Since a significant pulse results from the venting gases of high-explosive detonations at the same scaled burst depths, this is the most pronounced difference between close-in air blast from nuclear and high-explosive detonations underground. Peak overpressures from venting gases were only about one-third those of the ground-shock-induced pulse, while with high explosives at the same scaled burst depths they were about three times the ground-shock-induced pressure. This drastic reduction in venting-gas pressures accounts almost entirely for the fact that the close-in blast from nuclear charges is suppressed more by charge burial than that from high-explosive charges.

The peak ground-shock-induced air pressure is shown to attenuate less rapidly for a nuclear charge in basalt than for high-explosive charges in the same medium.

The TNT equivalent of the blast from Project Danny Boy can be deduced only from the peak overpressures of the ground-shock-induced wave. Since the waves are attenuating at different rates, the apparent blast yield ranges from 75 tons at the closer stations to about 325 tons near the station at 1120 feet.

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ARA	Allied Research Associates Inc. , Boston
ARF	Armour Research Foundation, Illinois Institute of Technology, Chicago 16
BOEING	The Boeing Company, Aero-Space Division, Seattle Attn: R. H. Carlson
EG&G	Edgerton, Germeshausen, and Grier, Inc. , Boston, Las Vegas, and Santa Barbara
ERDL	U. S. Army Engineer Research & Development Laboratory, Fort Belvoir
LRL	Lawrence Radiation Laboratory, Livermore
NDL	U. S. Army Chemical Corps., Nuclear Defense Laboratory, Maryland
REEC	Reynolds Electrical and Engineering Co. , Las Vegas
SC	Sandia Corporation, Albuquerque
SRI	Stanford Research Institute, Menlo Park
UCLA	University of California, Los Angeles
USC&GS	Coast and Geodetic Survey, Washington, D. C. and Las Vegas
USPHS	U. S. Public Health Service, Las Vegas
USWB	U. S. Weather Bureau, Las Vegas
WES	USA C of E Waterways Experiment Station, Vicksburg

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